

Coax-MIL Package Analysis of Intel Sapphire Rapids Xeon Gold 6430

Purpose:

Intel has used Air Core Inductors (ACIs) on package substrates to realize Fully Integrated Voltage Regulators (FIVR). The new product family, Sapphire Rapids, features a new coaxial magnetic composite core inductor called **(Coax MIL [coaxial magnetic inductor loops])**, which dramatically improves its performance and quality factor, resulting in reduced ripple current and increased efficiency of the fully Integrated Voltage Regulator (FIVR). This report will focus on planar magnetic composite cores.

2023.10.27

LTEC Corporation

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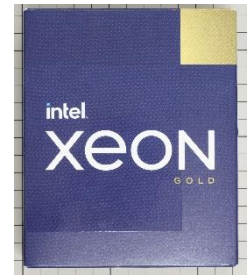
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Summary:

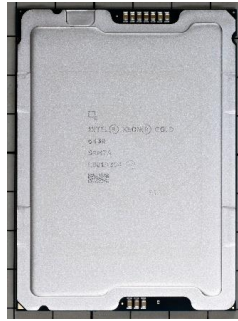
1. The package substrate has 22 layers, and the Coax MIL is implemented using the core layer
2. Coax MIL is an inductor that uses Through Hole (TH). The inside of TH is consist of non-magnetic material, and the area around TH is consist of the magnetic material.
3. The schematic on the right shows a simplified connection between the CPU Die and Coax MIL.

Connection to Die

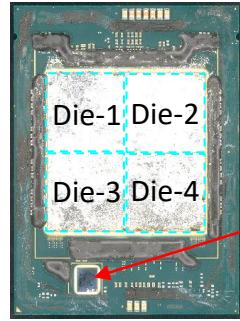
Connection to Die



product packaging



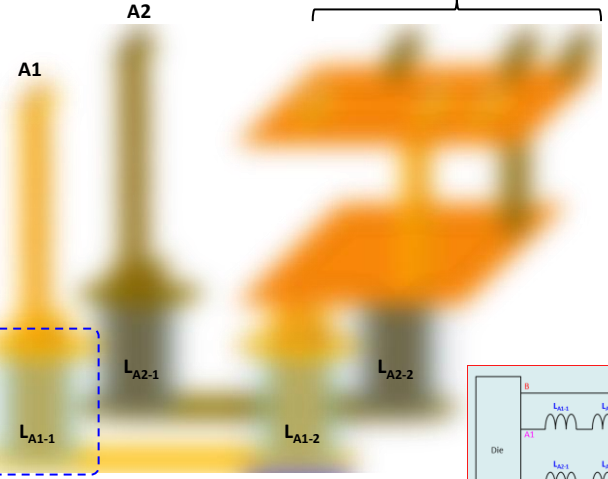
Package



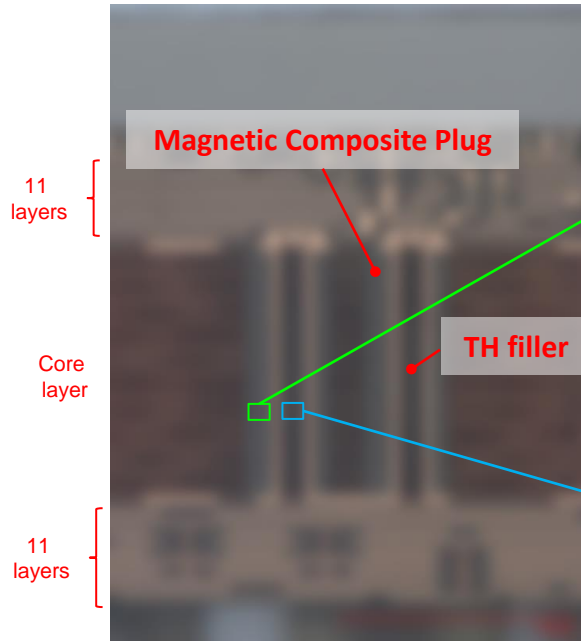
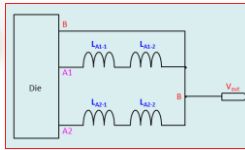
Substrate

programmable logic devices [PLDs]

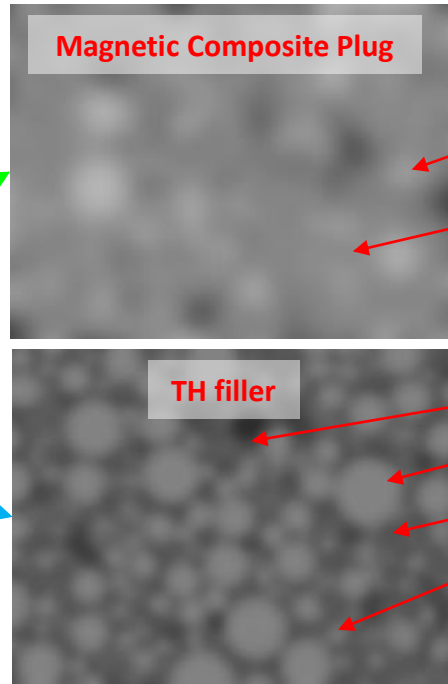
Coax MIL



Coax MIL Pattern



Cross-Section of Coax-MIL



- Filler : [Magnetic powder]
- Resin : [Epoxy]
- Filler : [Non-magnetic]
- Filler : [Non-magnetic]
- Resin : [Epoxy]
- Filler : [Non-magnetic]

[TH filler is common type that not have magnetic powder]

TH : Through Hole

1. Product Overview



Fig. 1-1 Image of product packaging



Fig. 1-2 Image of inner case



Fig. 1-3 Image of Package (Front)

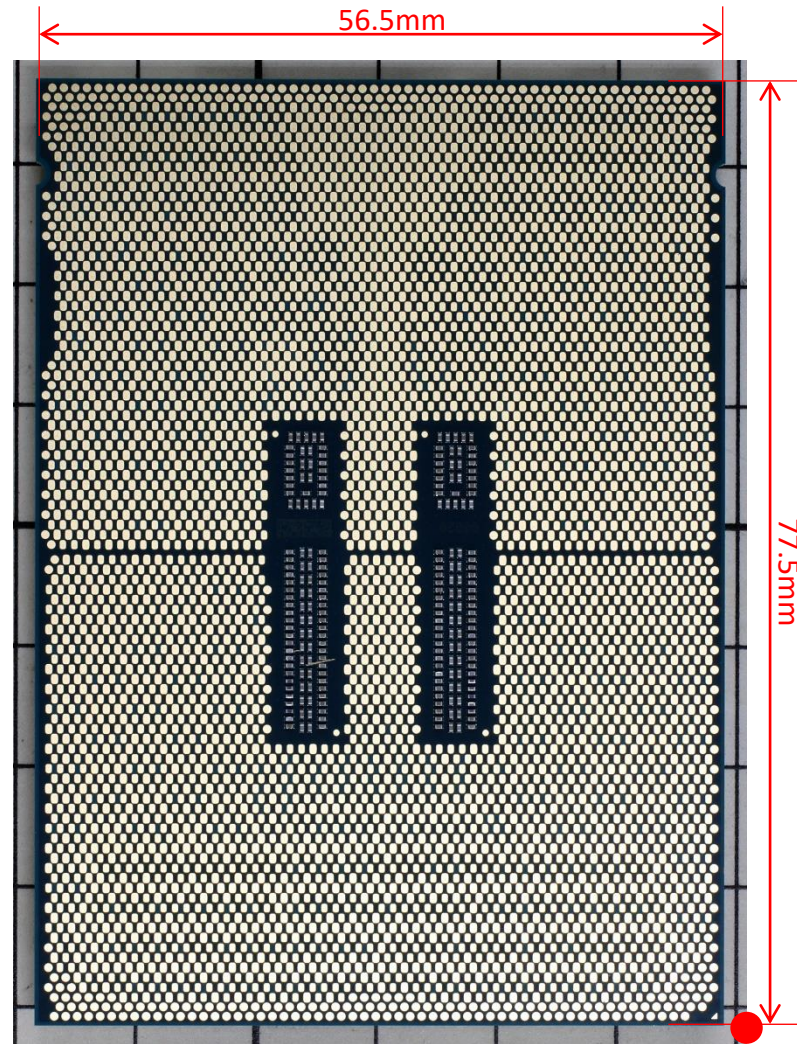


Fig. 1-4 Image of Package (Back)

2. X-ray observation

Array of Coax MIL

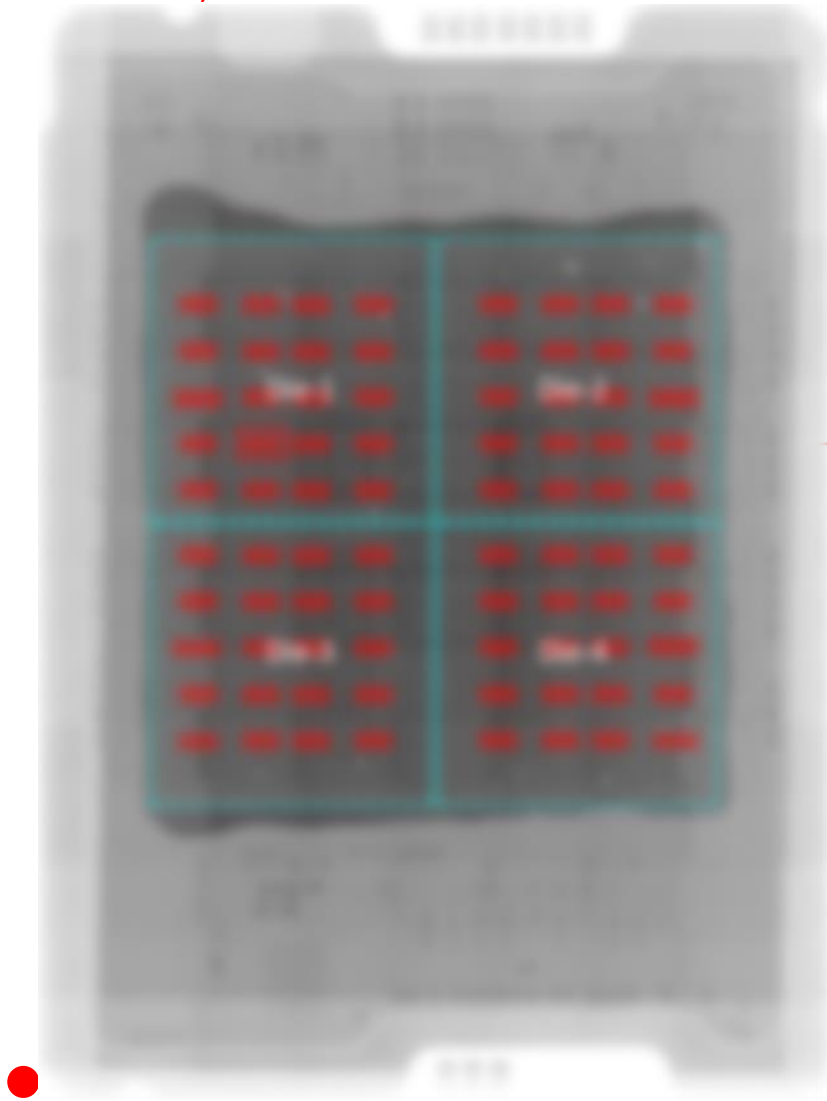


Fig. 2-1 X-ray image of the Package

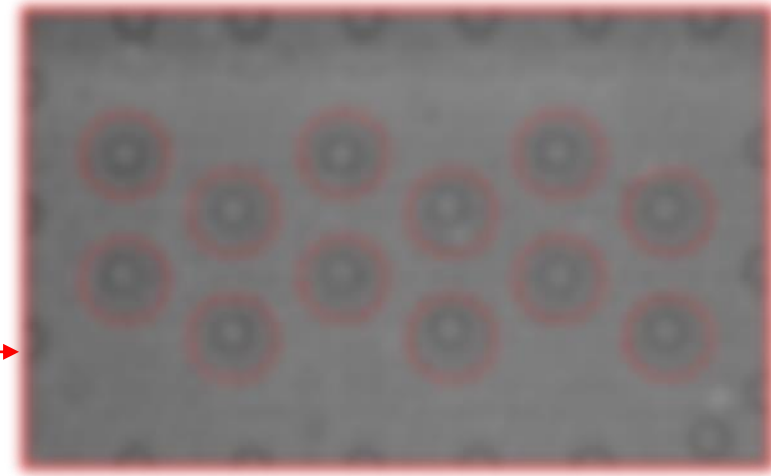


Fig. 2-2 X-ray image of an array of Coax MIL inductor

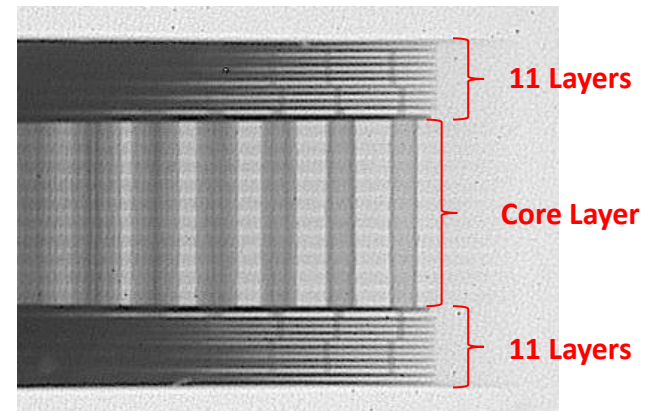


Fig. 2-3 Checking the number of interconnect layers

3. Substrate after heat sink removal

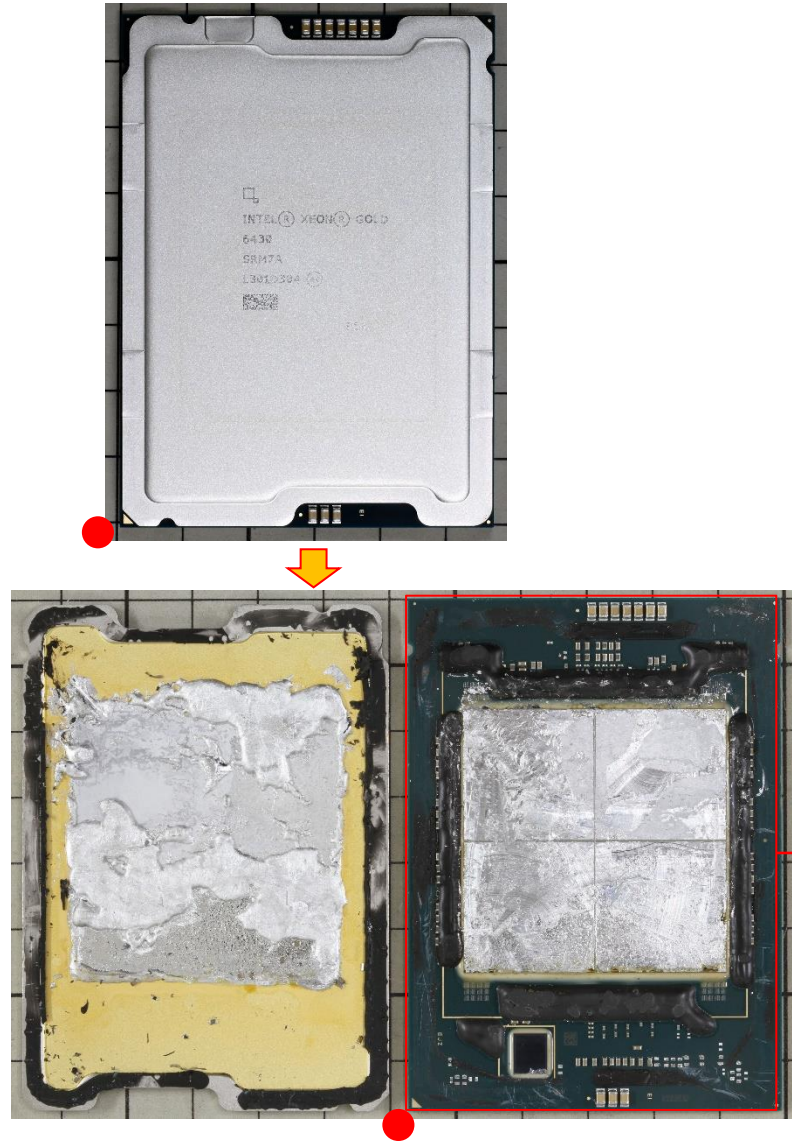


Fig. 3-1 Heat sink removal

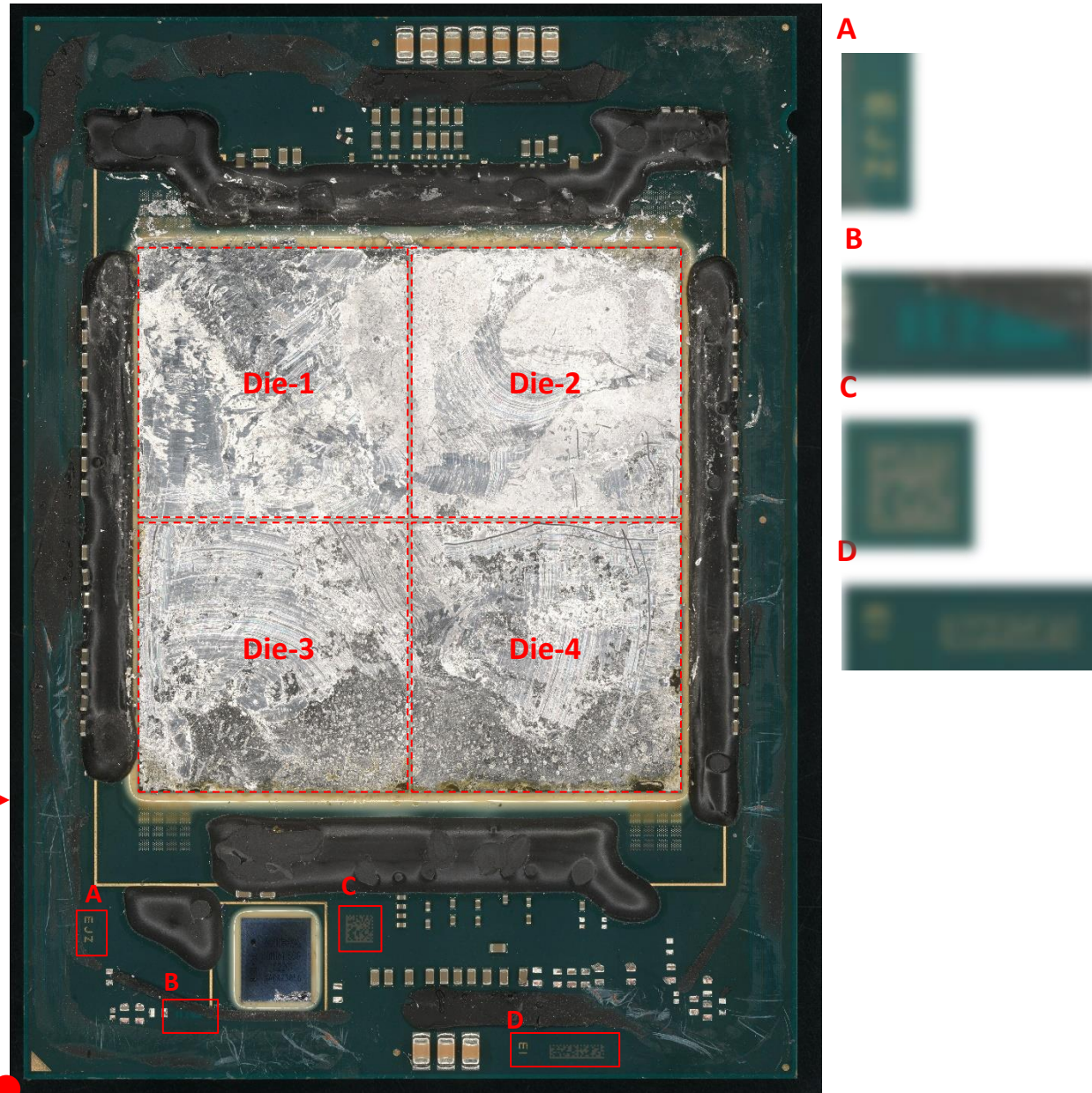


Fig. 3-2 Substrate after heat sink removal

Substrate wire tracing area:
Array of Coax MIL

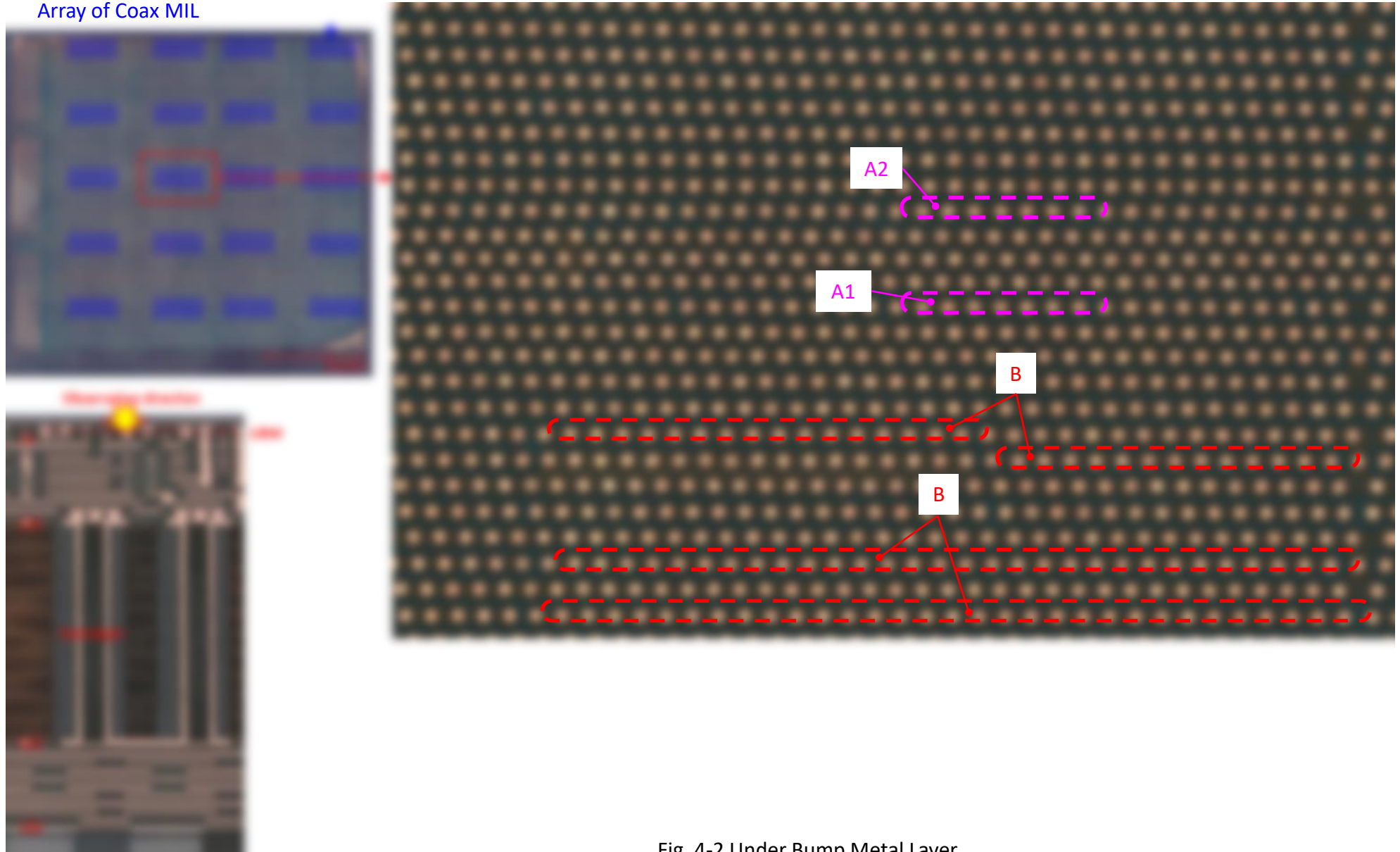


Fig. 4-2 Under Bump Metal Layer

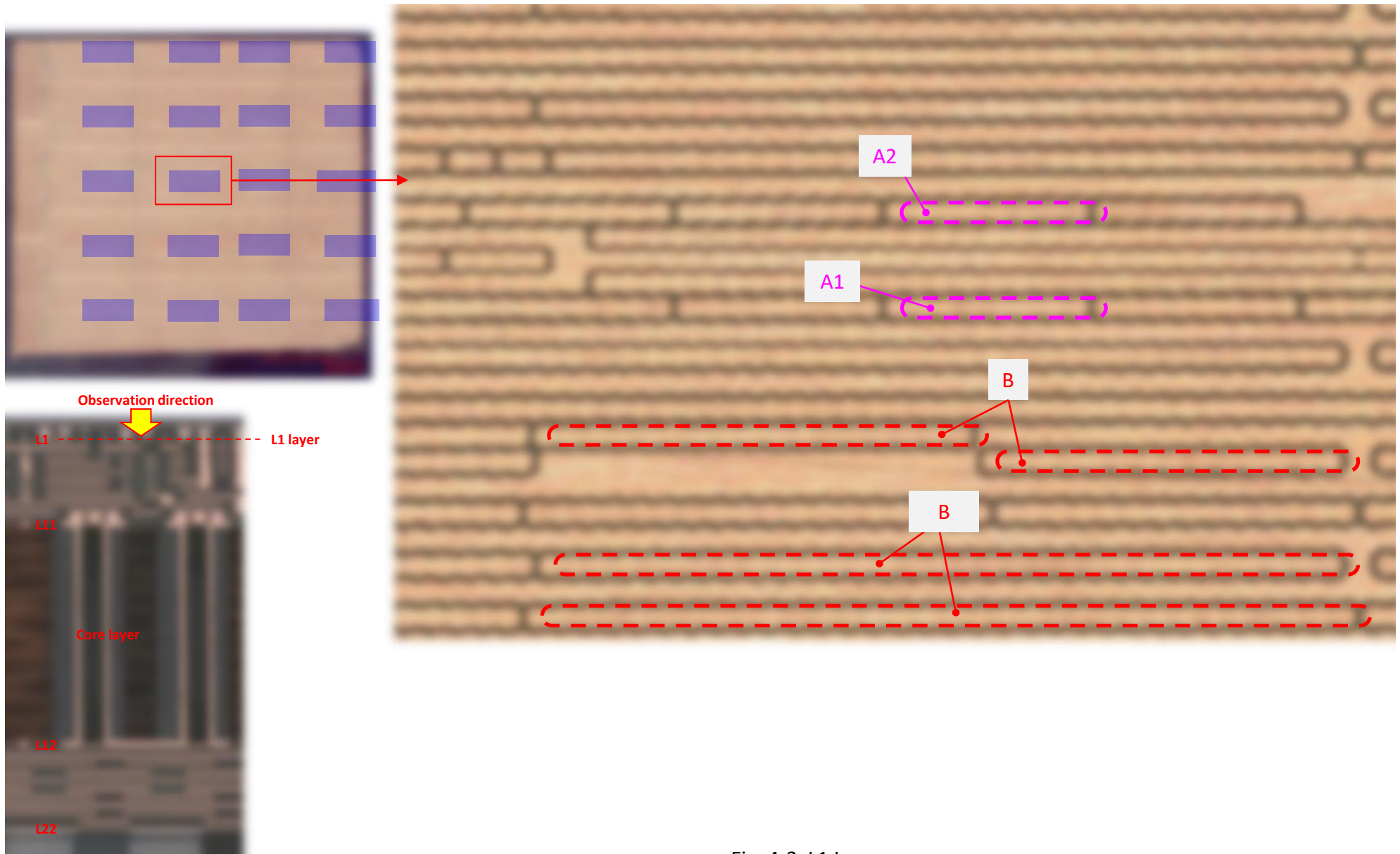


Fig. 4-3 L1 Layer

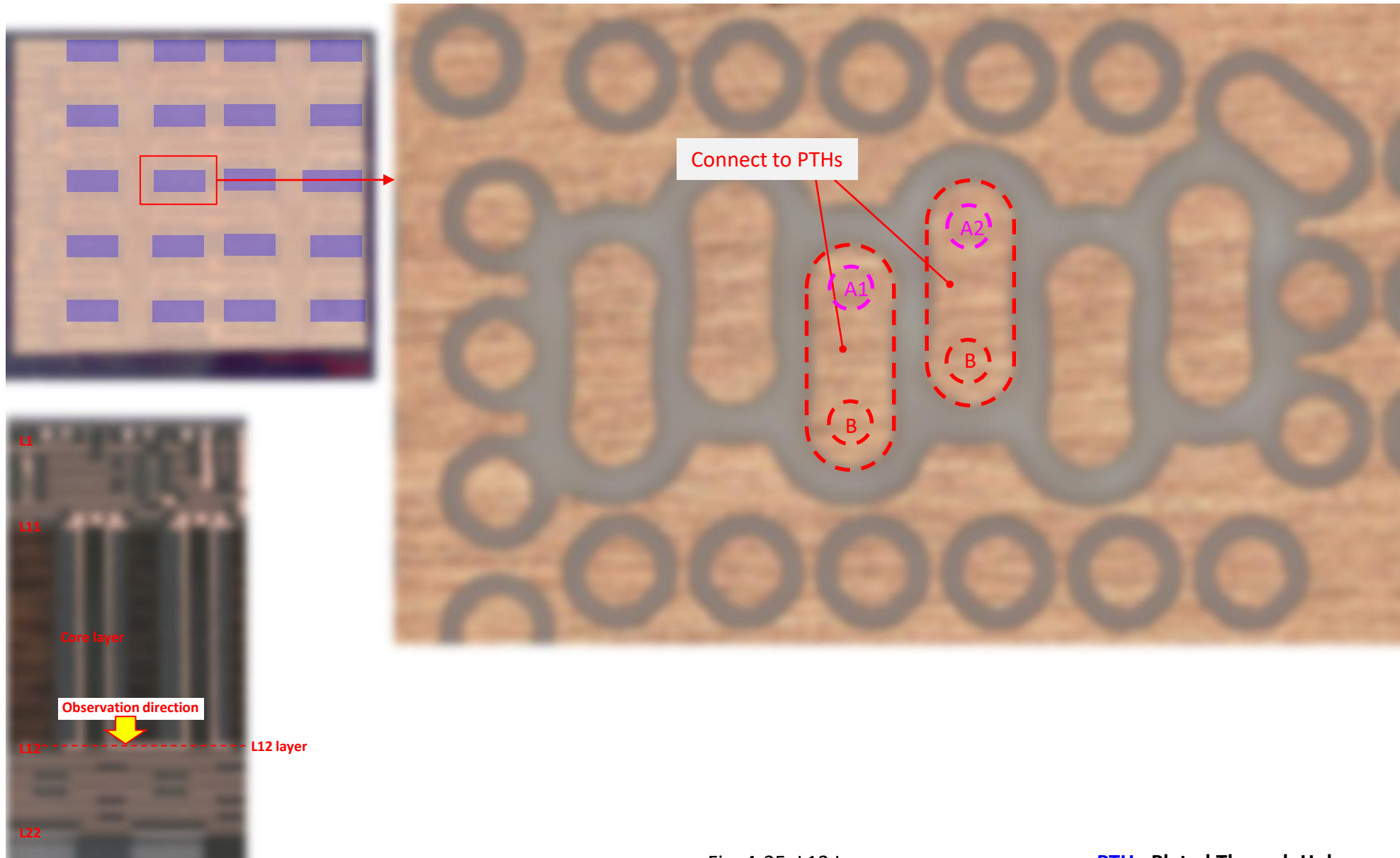


Fig. 4-25 L12 Layer

PTH : Plated Through Hole

5. Schematic diagram

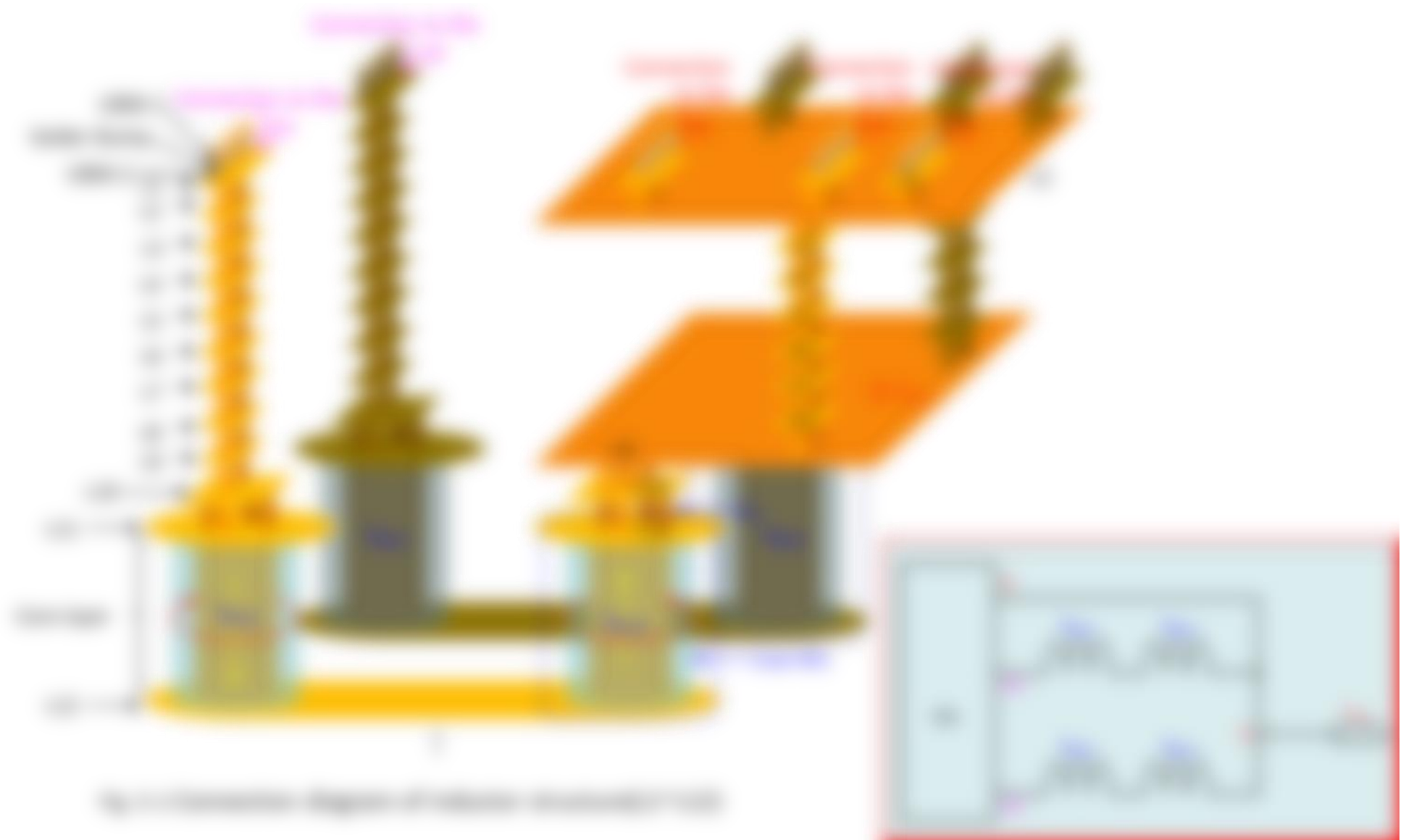


Fig. 5-2 Equivalent circuit of interconnect and inductors

6. Cross-section

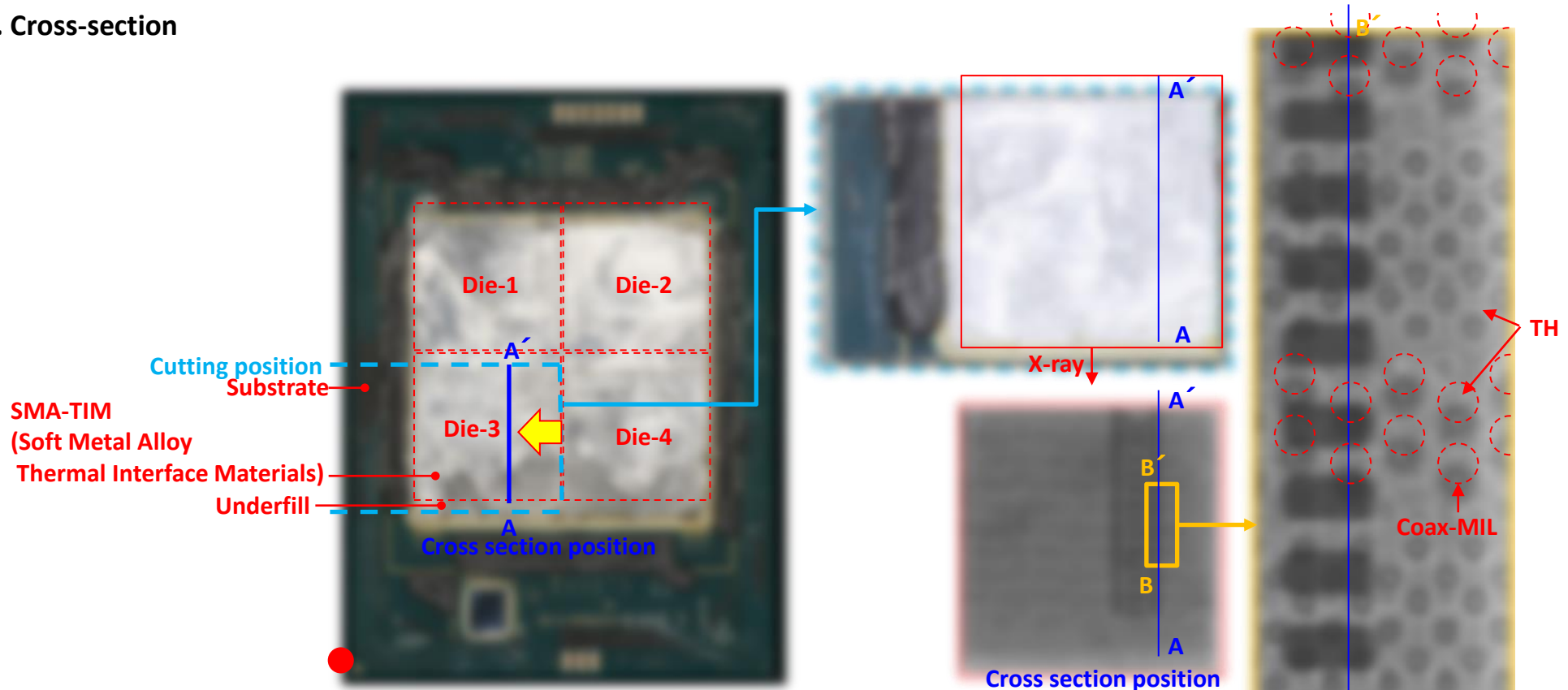


Fig. 6-1 Cross-section position of Package

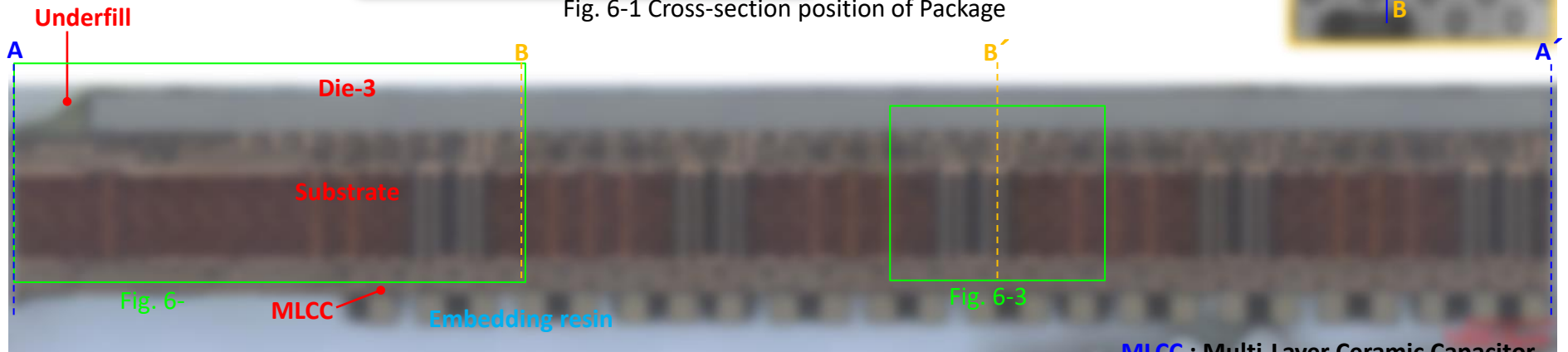


Fig. 6-2 Image of Cross-section

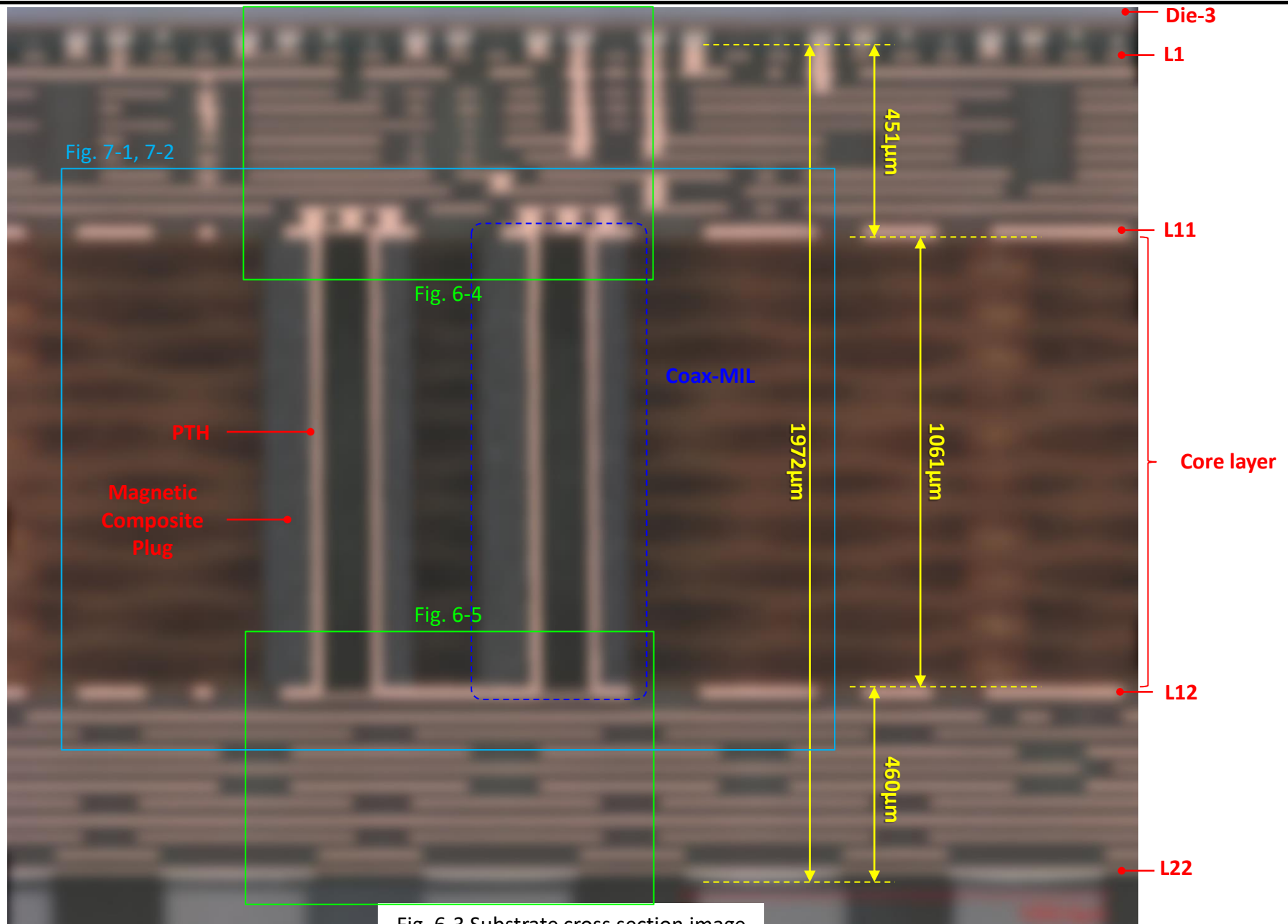


Fig. 6-3 Substrate cross section image



Fig. 6-9 Micro-bump cross-section image

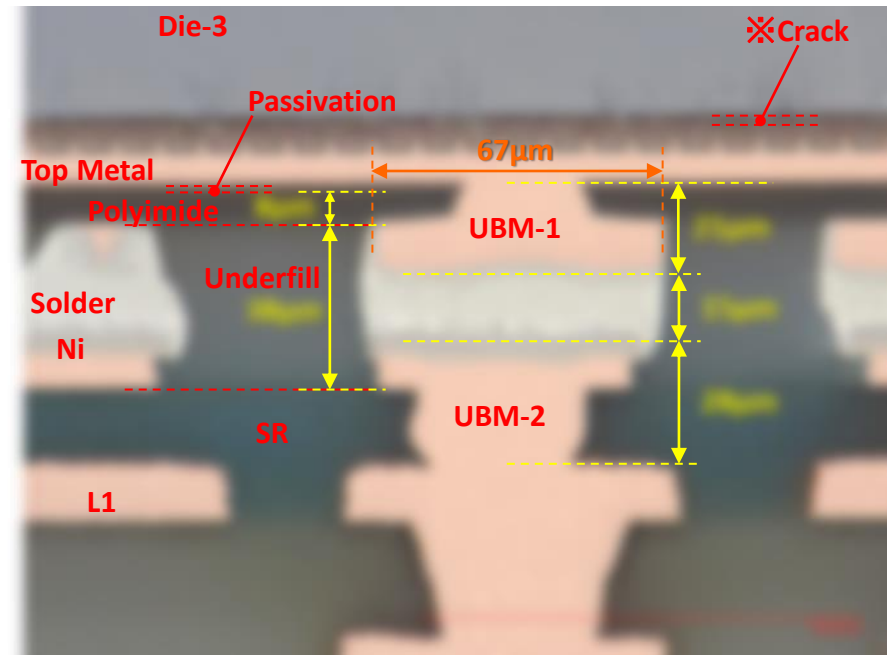


Fig. 6-10 Micro-bump cross-section image

7. Coax-MIL inductor material analysis (EDX)

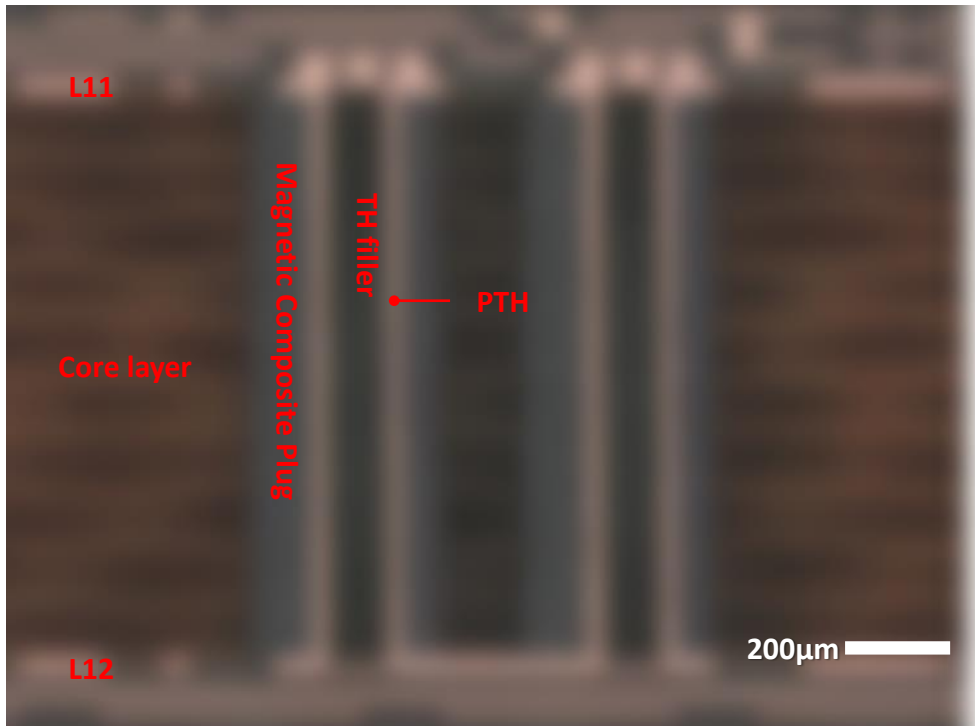


Fig. 7-1 Coax MIL cross-section image

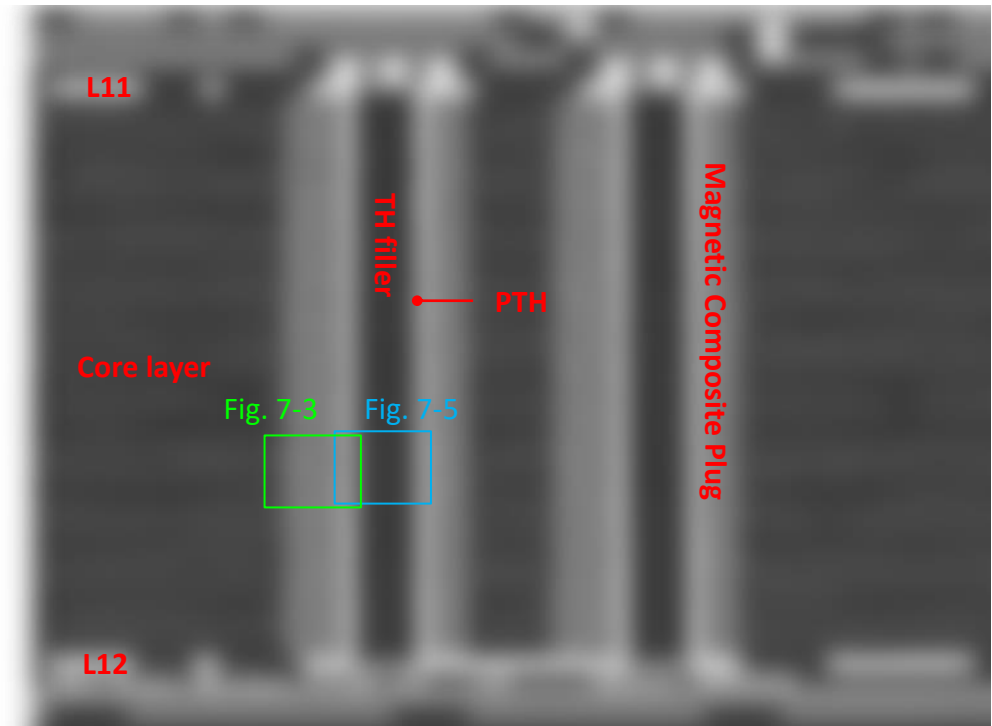


Fig. 7-2 Coax MIL SEM image

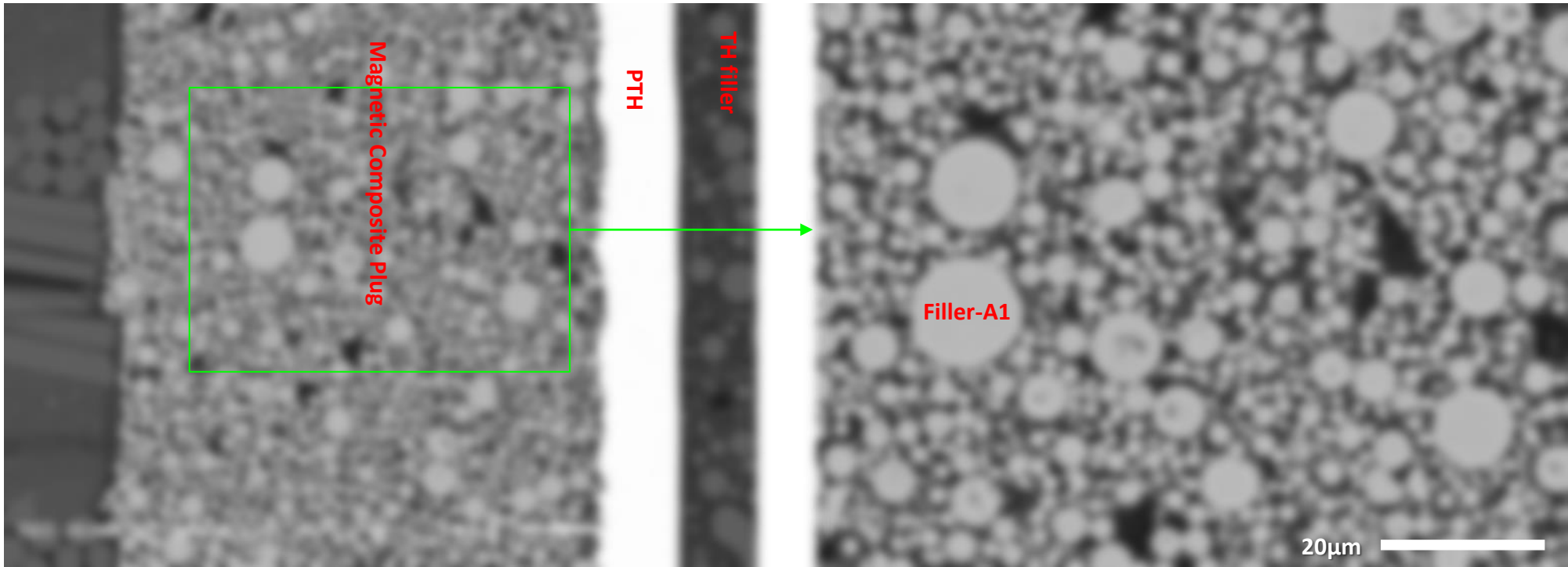


Fig. 7-3 Coax MIL SEM image

Fig. 7-4 Coax MIL SEM image

Point 1

Analysis conditions

- Acceleration voltage: 20kV
- Collection time: 10min

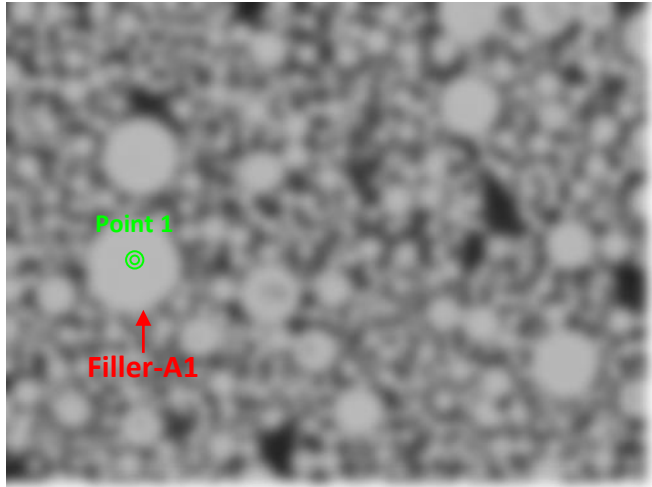


Fig. 7-7 Coax-MIL Filler Analysis point1

[EDX Analysis result]

main elements

Si, Mn, Fe, O, C

Other detected elements:

C (Carbon coat for conduction)

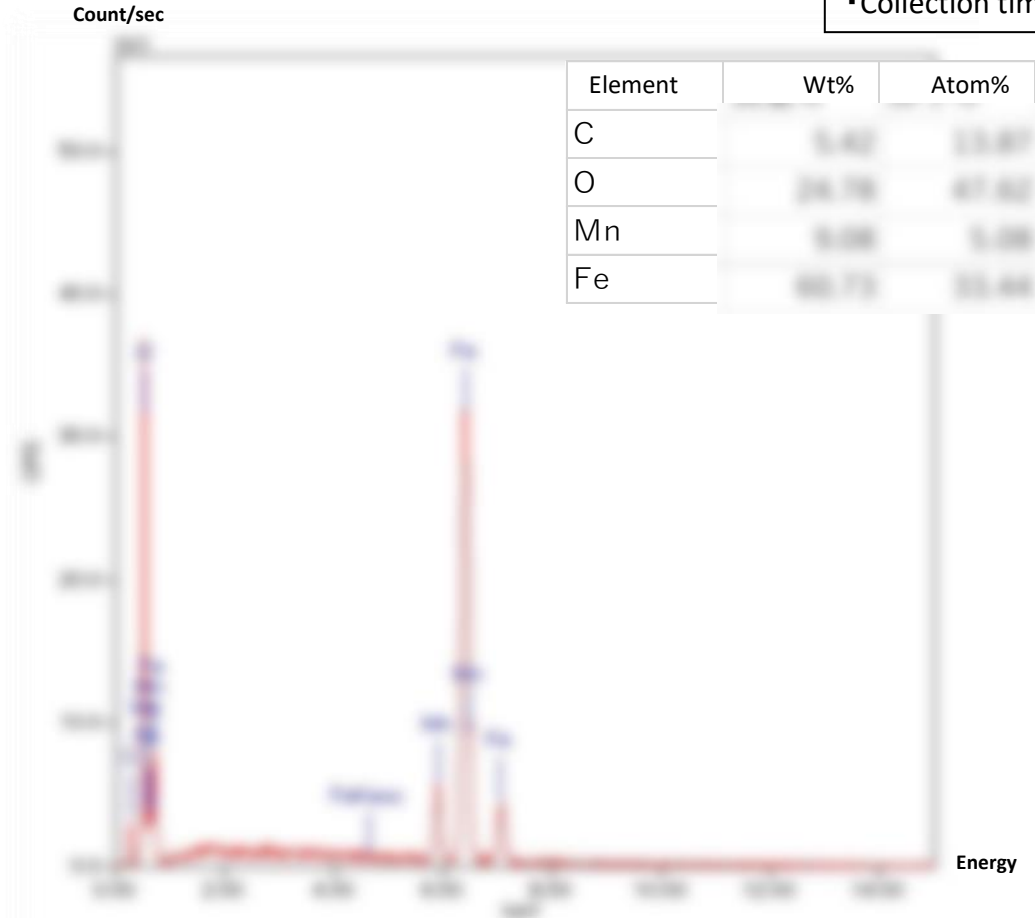


Fig. 7-8 EDX spectrum result Point 1

Appendix (1): Comparison with ACIs and Coax MIL [Xeon Gold 6430, Xeon Silver 4310, Alder lake]

Xeon Gold 6430
(22 layer [1972um(t)])
[4th Gen intel Xeon]

Inductor uses core layer

Xeon Silver 4310
(22 layer [1660um(t)])
[3rd Gen intel Xeon]

Inductor layers used: L11-17

Alder lake
(10 layer [1150um(t)])
[12th Gen Core i7]

Inductor layers used: L6-10



L11 – Core layer - L12 [1115um(t)]

L11 – Core layer – L12 ~ L17 [1000um(t)]

L6 ~ L10 [203um(t)]



Appendix (2): References

1. Integrated Voltage Regulator Efficiency Improvement using Coaxial Magnetic Composite Core Inductors
* 2022 IEEE 7th Electronic Components and Technology Conference (ECTC) *

2. (Related patents)

- 202200000000000000 "Magnetic inductor device and method"
- 202200000000000000 "Inductor device and a circuit with dual-wound and unidirectional current flow"
- 202200000000000000 "Damped core air gaps for inducting inductance within a package"
- 202200000000000000 "MAGNETIC CORE STRUCTURE IN A PACKAGE"